urated yellow or blue. The points at which this happens as also that at which the primary colors fade out, depends on the saturation, the size of the retinal area affected, the brightness of the color, the brightness and color of the back-ground, and the radius of the retina along which the colors are advanced. (5) The best method for fixing the point at which the color fails to be seen is to make the back-ground exactly as bright as the colored spot becomes when it has lost its color, in which case it fades into the back-ground and becomes wholly indistinguishable. (6) The colorless brightness or "white valence" of two colors may be assumed to be equal when on losing their color they become indistinguishable from the same back-ground; and the "color valence" of primary red and green may be considered equal when, being mixed in equal quantity the y produce white. Fields of primary red and primary green examined u nder exactly parallel conditions, (*i. e.* when they have equal "white valence" and equal "color valence;" when they are of the same area, are observed with the same portion of the eye and against the same back-ground,) become colorless at the same distance from the center of the field. The same is true for primary yellow and blue. (7) From this it follows that the red sensibility and green sensibility decline exactly together as the periphery is approached; likewise the blue and yellow sensibilities, but much less rapidly. (8) No fixed point can be assigned where these colors will invariably disappear, though such a point can be found for any given set of conditions. (9) White light appears white at all points of the retina. All colors matched on the red-green sensitive part of the eye (except the *macula lutea*) match on all other parts, but colors that match on red-green blind areas, while they match for all other red-green blind areas, do not necessarily match for those that are red-green sensitive. It is hardly necessary to say that most of these observations, which in part support and in part supersede previous observations, are very much more easily explicable on the color theory of Hering than on that of Young and Helmholtz.

The experiments of Hess were conducted with great care; when spectral light was used the eye was kept in the dark for from 15 minutes to half an hour before observation; and care was taken to avoid fatiguing the retinal spot worked upon. The device (one of Hering's) for obtaining a definite area of a definite color in a field of exactly the right shade is especially simple and effective. Through a small round hole in a horizontal screen of gray paper the observer looks down upon the horizontal disc of a rotary color mixer. If the hole is clean cut, the portion of the disc seen below appears in indirect vision simply like a colored spot on the surface of the screen. By changing the inclination of the screen with reference to the light its brightness can be considerably varied, and with a set of interchangeable screens any desired degree can easily be secured. With the same apparatus the "white valence" of colors at the point of disappearance can be measured by the width of the black and white sectors required to make a gray with the disc of the color mixter that shall be indistinguishable from the gray of the screen when the eyes are in the same position as that at which the color disappeared. E. C. S.

Ueber die Hypothesen zur Erklärung der peripheren Farbenblindheit. Prof. EWALD HERING. v. Graefe's Archiv für Ophthalmologie, Bd. XXXV, H. 4, 1889.

In this article, which in a sense furnishes a theoretical and polemical part to the article of Hess above, Hering subjects the explanations of peripheral color blindness advanced at various times by Helmholtz and Fick to a vigorous examination. The first view, conjecturally advanced by Helmholtz, was that the sensibility for red in the peripheral zone was less than for green and blue, approximating a red blindness. This

however was contradicted by observations, among others, mentioned by Helmholtz himself, namely, that red and green appear yellow when moved toward the periphery (according to the Young-Helmholtz theory a union of red and green sensations are necessary for yellow), and that blue became a grayish white, for which on that theory all the sensations must be present. The colors that are still seen should also look more saturated as the others fail, but directly the reverse is the case. To avoid this difficulty the hypothesis of Leber and Fick was proposed. Fick assumed, instead of an absence or loss of function in any of the three kinds of nerve fibers, that all three were functional, but that the degree in which each kind was excitable by the various homogeneous lights of the spectrum changed continuously from the center toward the periphery, so that in the so-called red-blind zone the red and green fibers had a like degree of excitability toward all lights, and in the extreme peripheral zone all three kinds had the same degree. Such a hypothesis adapted to fit a photochemical explanation of vision is given by Helmholtz in the new edition of of his Physiological Optics.

Against this hypothesis, which Hering regards as itself destructive of the Young-Helmholtz theory, he urges the theoretical objections that it is illegitimate to assume three color sensations where two or only one would be sufficient to satisfy the law of color-mixing, and at the *same time* to deduce from that law the dictum for the center of the retina that there can only be three primary sensations, which certain of the representatives of the theory, (though not Leber and Fick) have done. Furthermore since the color-sense changes on the retina continuously, an infinite number of different ratios of excitability must be supposed. Theoretical objections aside, however, the theory breaks down in explaining facts such as those brought out by Hess, whose results Hering here resumés. Moreover, in order to explain a part of these results on the Young-Helmholtz theory the assumption is forced that *all* colors remain unchanged in color tone as they move toward the periphery, which is flatly contradicted by others of them. Whence it follows "that the Young-Helmholtz theory in general offers no possibility of explaining the above cited and for the most part already long known facts, and that it is by them alone to all intents refuted." Another explanation of Helmholtz, advanced at the same time with the last, was this, namely that when one of the primary sensations is wanting, we learn by experience which sensation of those remaining corresponds to the most frequent and intense sensation received from luminous bodies, i. e., white. From this as a basis we "interpret the rest of the perceptible colors as colors of a line which is laid in the color triangle through the place of white, parallel to the line joining the two fundamental colors yet retained. This would go, if red were lacking, from yellow through white to blue" (Phys. Opt. 2nd. ed. p. 374). Though yellow and blue are the colors seen on the "dichromatic" parts of the eye. this statement as it stands contains a palpable error; for it is when green and not red is lacking that the line would go "from yellow through white to blue." Helmholtz explains that we do not recognize the colors seen at the periphery in accordance with the actual sensations received there for the same reason that men for thousands of years failed to discover that all colors were not seen with the periphery. To this Hering replies that men, to be sure, did not recognize the peculiarities of the color vision of the periphery because they never had need to attend to them. When attention is once given, the color is recognized as it is seen; a violet color is seen blue, and not the clearest knowledge that it is violet can help it in the least. The facts that Hering finds thus in such disaccord with the theories of Helmholtz and Fick, are so easily explicable, he thinks, on his own theory that he waives detailed explication.

E. C. S.